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Vibrating oxidized iron surfaces have been shown experimentally to produce modulated microwave reflections which are not present for clean surfaces. An experimental and theoretical program is pursued to explain this effect in terms of the strain dependence of resistivity of the iron oxides, and of the oxide junctions between metallic grains.

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MICROWAVE REFLECTIONS FROM VIBRATING INHOMOGENEOUS CONDUCTING SURFACES

During the initial period of this investigation the major effort has gone into developing both the experimental program and the theoretical framework within which we have proposed to study the interaction of microwaves with vibrating inhomogeneous conducting surfaces. We have made good progress in all aspects of the work.

A. Standardized Configuration for Studying Microwave Properties

We have set up an x-band cavity with a capacitatively coupled end wall that can be driven acoustically about its static location in essentially symmetric modes of a circle clamped at the circumference. Monitoring of the cavity resonance yields both the shift in resonant frequency and the cavity Q as a function of acoustic amplitude and these data give a direct measure of the change of microwave properties of the end plate with vibration. Since the end plate is interchangeable, and the contact impedance of the end plate clamping is reproducible, we thus have a versatile and simple configuration for studying the response of a variety of materials and surface treatments. To enhance the sensitivity of our measurements, we monitor signals at both the fundamental and the second harmonic of the acoustic frequency, both at the center of the resonance and at the ahlf-power points. We estimate that we can detect changes as small as 0.01 db in the reflection coefficient of the end wall.

B. Preliminary Microwave Results

Measurements have been carried out on copper and iron foils. For copper and clean iron we observe no change in cavity Q, and the results for Q itself agree with calculated predictions for the geometry in question. However, for iron exposed to moisture to form a layer of rust, the Q of the end plate is noticeably lowered, and it also changes with vibration amplitude. A first analysis of the data indicates a relationship $\Delta\rho/\rho = 12A$ for the change in resistivity ρ of the end plate with driving amplitude A (in cm) of the end plate. At the usual value of A, about 10^{-3} cm, this indicates a shift in resistivity of a percent or so, and would lead to a change in reflection coefficient for microwaves of between 20 and 30 db below the main signal.

It must be emphasized that, while by themselves fully reproducible, these results cannot yet be taken as representative of weathered iron surfaces since we have not studied the range of effects of systematically controlled exposures to different environments.

In a modification of the experiment the foil at the cavity end wall is formed into a fold running perpendicular to the lines of current flow. This simulates the effect of a crack in a metal surface forcing the current lines to deform. When pressure is exerted on both sides of the fold, foils of oxidized iron show an appreciable change in Q, while clean iron or copper are much less affected by the quality of the contact within the fold. This experiment confirms qualitatively that stress on cracks containing oxidized material can affect the microwave resistance of a metal surface.

Both of these results indicate that vibrating inhomogeneous surfaces can produce a considerable modulation of microwave reflections. The exact origin of the observed effects has not yet been established.

C. Determination of Material Constants

To obtain additional information about the electrical properties of the surfaces of interest, we have put into operation an experiment that measures directly the strain sensitivity of the DC resistance of thin metallic layers. The layers are deposited on scratch-free mica and the resistance is determined when the mica is flat and when it becomes an arc of a large circle. Since for normal metals, to which all measurements must be standardized, the observable changes in resistance are very small, the system has been designed for good long-range thermal insulation and stability. It is capable of monitoring relative changes due to strain as small as 10^{-5}.

We have shown experimentally that for these samples iron layers of considerable thickness can be prepared by evaporation. Furthermore, by interrupting the evaporation, layer structures of oxides and metallic iron can be produced at will. After such testing at DC, these same samples can be transferred to the cavity end wall for their response at microwave frequencies. Pure and weakly oxidized iron films show a strain sensitivity of resistivity comparable to that of other metals, and an anisotropy of the same sign as that of silver. The properties of heavily oxidized films and pure oxides remain to be investigated.

Using similar oxidations techniques we have produced Fe-FeO_x-Fe junctions of low resistance and showing non-linear behavior characteristic of tunneling at high current densities. These techniques lend themselves to extension to higher oxidation, and consequently larger tunneling resistance and non-linearities at lower current densities in junctions which can be adapted to the strain sensitivity of resistance measurements.

D. <u>Theory</u>

Theoretical efforts have progressed in the various areas associated with the experimental work. First of all, cavity calculations have been carried out to obtain a quantitative analysis of the microwave measurements in the configuration used in the experiment. Secondly, the cavity results have been transformed to obtain the equivalent microwave single reflection coefficient for such surfaces, and the effect of strain on the reflections. Third, the calculations have been extended to include depth-dependent variations of the electrical properties of the vibrating end plate. Finally, we have set up the formalism for treating a microscopically inhomogeneous medium containing more than two components of different electrical properties, in the framework of effective medium theory. This formulation can be extended in a straightforward manner to high frequencies. However, the number of material parameters entering into the results becomes so large that we have decided to hold off further work until some of these parameters, or their ranges, become better known from our experiments.

There have been no publications during this initial phase of the investigations.